A Critical Flaw in the American Fisheries Society Initiative to Protect Marine, Estuarine, and Diadromous Fish Stocks: Failure to Account for Depensation

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Traditional fish population models predict higher rates of growth at lower abundances because of reduced intraspecific competition, a process called compensation. An alternative and supposedly much less common phenomenon, depensation, occurs when population growth rates are reduced at lower densities. In its most extreme form, a population is not able to replace itself from generation to generation, even in the absence of significant fishing mortality. Liermann and Hilborn (1997:1,976) give examples such as "predator pits, reduced reproductive success, impaired aggregation, conditioning of the environment, efficiency of food location, and inbreeding". Depensation is also referred to as inverse density-dependence or the Allee effect (Myers et al. 1995) but the latter term is only a sub-part of depensation. Mechanisms underlying Allee effects are physiological and behavioral (Frank and Brickman 2000).

Depensation, by its very nature, will always be difficult to detect from quantitative population data. When abundance of a species enters a size range subject to this process, it becomes unstable and must head to what Peterman (1977) called a domain of stability. Thus, there is only a limited opportunity to create spawner-recruit data points within an unstable range of population abundance subject to depensation. Frank and Brickman (2000) listed 10 diverse species, including passenger pigeons, in which Allee effects were either demonstrated or hypothesized. Spawning populations of green sturgeon (*Acipenser medirostris*) have disappeared from at least six Pacific Coast river systems even though white sturgeon (*A. transmontanus*) have recovered from low abundance in several of the same rivers (EPIC et al. 2001). The only plausible explanation is that greens, with their larger eggs and predominately marine life history, are subject to depensation, while whites benefit from compensation.

In the recent American Fisheries Society (AFS) Initiative, the project manager and author or senior co-author of primary publications that resulted was J.A. Musick (Musick 1998; Musick 1999; Musick et al. 2000a; Musick et al. 2000b). Mr. Musick was repeatedly cautioned of a need to deal directly with the process of depensation, including sections from three separate reports (Wright 1999a; Wright 1999b; Wright 2000) that were all cited in Musick et al. (2000b). In spite of these repeated attempts, any meaningful treatment of depensation was ignored. The first of three warnings (Wright 1999a:4-5) was as follows:

"For all of the populations discussed in this petition, the greatest danger with a small stock size occurs when predation, parasites and/or disease (i.e, any natural mortality cause) leads to a situation where the highest percent mortality occurs at low abundances of juveniles and/or adults. Peterman (1977) stated that populations with two or more "domains of stability" must be managed accordingly. In these cases, two or more different mortality processes combine in a series to create a stock-recruitment curve with more stable points than the single one exhibited by the standard Ricker model. In one case, an unfished population would be stable at point A, and could be continuously exploited without permanent harm as long as it never dropped down to point B. Below this point, the population would move toward extinction, even if harvesting was completely stopped. In the second case, a critical spawner abundance would also exist, but a population falling below point B would not go toward extinction but toward a lower stable equilibrium (point C), which would be very unproductive for harvesting. Elimination of all harvest would still not permit the population to return to the higher abundance near the upper stable point."

The issue of depensation was discussed in Musick (1999) but he concluded that no special category or treatment was needed to address the process, probably due to its apparent rarity and/or a belief that it could only be manifested at very low population sizes. He was influenced by the fact that Myers et al. (1995) had found clear-cut depensation in only 3 stocks out of 26. Myers et al. (1995) examined stock collapse and potential depensation in 128 fish stocks but had the necessary statistical confidence for detection in only 26. Icelandic spring-spawning herring (*Clupea harengus*) and two stocks of anadromous pink salmon (*Oncorhynchus gorbuscha*) were the three showing definite depensation. It was noted that the smaller pink salmon stock "exhibited depensation after a decline of only 1/50" (Musick 1999:10). However, this was one of the same populations examined by Peterman (1977) and depensation was evident well before reaching a low point at 1/50. In most cases, it should be possible for fish populations to rebuild "unless environmental or ecosystem-level changes occur that alter the underlying dynamics of the stock" (Myers et al. 1995:1,108). Thus, this particular form of depensation can occur at any level of population abundance. After construction of multiple dams in the Columbia River system, all spawner-recruit data points for upper river wild steelhead (*O. mykiss*) fell below the replacement line (WDFW 1997).

With respect to the Icelandic spring-spawning herring, Myers et al. (1995:1,107) stated that "Strong environmental changes have been identifed that likely affected this stock and may have been responsible for its demise." Their comment for the two pink salmon stocks "which have been driven to extremely low levels by fishing and habitat loss" is similar. In both cases, depensation was in evidence well before the stocks reached their smallest sizes.

Musick (1999) also relied on work by Punt (cited as in press in Musick 1999) who had used a population reduction of 1/1,000 as the operational definition for extinction or level at which critical depensation might occur. This particular analysis was restricted to six marine fish species and odds of even finding depensation (3 of 26 in Myers et al. 1995) would be slim. In addition, a 1/1000 threshold could be far below a population abundance level when depensation might first be detectable. It might be appropriate for the Allee effects alone but would be woefully inadequate for depensation causes related to habitat modification or increased predation.

Unfortunately, one of the first actual applications of the AFS criteria was made by the National Marine Fisheries Service (NMFS) in their assessment of status of the Cherry Point Pacific herring (*Clupea pallasi*) stock in the State of Washington (Stout et al. 2001). This population, which was once largest in the region, was deemed to be of Medium Productivity and then classified as Vulnerable since it had a decline of over 95% in a 15 year period. The total period of continuous decline spans over 20 years (Stout et al. 2001). There has to be something fundamentally wrong with criteria which classify a fish population as "medium" in spite of a demonstrated inability to replace itself for two decades. A Vulnerable label is essentially meaningless in interior state marine waters since it can only encourage strictly voluntary actions. It is one step below the minimum necessary for listing under the Endangered Species Act (ESA, Threatened). This is the only viable option that most people recognize as being available to change ecosystem management in a positive direction and is manifested in the high priority that many environmental organizations give to ESA petition processes. The 1996 Sustainable Fisheries Act is often touted as a primary mechanism for responsible management of marine fish resources (as opposed to ESA) but it does not apply to interior state waters (Weeks and Berkeley 2000; Weeks and Parker 2002).

Detection of depensation in marine fish populations is normally thwarted by a confounding factor of simultaneous high fishing mortality but Cherry Point herring are unique in that fishing mortality was relatively low throughout two decades of continuous decline and cannot be used as a plausible alternative explanation for demonstrated replacement failure (Wright 1999a; Stout et al. 2001). The process of depensation was evident after 10 years or at a point of about a 50% decline in abundance. Annual natural mortality rates have also increased markedly (from 30-40% to 60-70%) and have a strong inverse correlation with rate of population decline. This has been accompanied by the expected major decrease in average age of fish in the population and lower average age of first time spawners. Larval herring from this stock are significantly smaller than those from other populations. In any given year, there are now significant numbers of fish from only two or three brood years instead of five, which was normal in the past. In addition, only a small fraction of available area used in the past is now actually used for spawning (Wright 1999a; Stout et al. 2001). All possible fish population indicators of depensation are clearly evident.

Plausible depensation mechanisms are available. The Cherry Point area, where herring spawning, egg incubation and larval rearing occurs, has extensive industrial development (Wright 1999a). Recent evidence shows a high rate of larval abnormality as compared to other herring populations and chemical contamination is a suspected agent (G. Bargmann, WDFW, personal communication). This is present in conjunction with small larval size at a time when natural larval mortality rates can be as high as 10% per day (Wright 1999b). A third probable cause is recent significant increases in marine mammal populations, a major source of predation (Wright 1999a; Stout et al. 2001). Harbor seals (*Phoca vitulina*) are year-round residents and most abundant, increasing 5-15% annually at different sites. California sea lions (*Zalophus californianus*) rank next in abundance, are present from late summer to late spring (mainly males), and are increasing at about 5% per year (Stout et al. 2000). A number of other herring stocks are subjected to this same increased predation pressure but have not declined.

The Vulnerable Cherry Point herring finding by Stout et al. (2001) was accompanied by an ESA determination that the stock was merely one component of a much larger Georgia Strait Distinct Population Segment (DPS). However, the Washington Department of Fisheries (WDFW) recently released results from genetic studies, stable isotope ratio analyses, Canadian herring tagging, and studies of contamination in herring that will provide a technical basis for reconsideration of that particular decision (G. Bargmann, WDFW, personal communication). These data are in addition to significant life history differences already recognized by Stout et al. (2001).

Cherry Point herring home to discrete spawning grounds that are wide open to the prevailing weather while other stocks spawn in sheltered inlets, sounds, bays and estuaries. They spawn later than any other population in the region. Spawning extends from early April to early June, peaking about May 10. Peak of spawning for other Puget

Sound herring stocks occurs during the last week in February and first week in March. Cherry Point fish are also known to make major offshore migrations to summer feeding grounds on the continental shelf. Many other herring stocks are resident to Puget Sound and Georgia Strait. However, the Vulnerable finding derived from AFS criteria will still be in effect and unchallenged even if the stock becomes part of a smaller DPS or a single DPS.

The core of the argument presented by Stout et al. (2001) for a broad geographic herring DPS comes from the metapopulation concept which Levins (1968 cited in Stout et al. 2001:93) defines are follows:

"a population of populations which were established by colonists, survive for a while, send out migrants, and eventually disappear. The persistence of a species in a region depends on the rate of colonization successfully balancing the local extinction rate."

Under this metapopulation concept, individual populations become very unimportant and in fact will be expected to eventually go extinct as a normal process. However, this hypothesis becomes untenable if a major component of this supposedly homogeneous population has significant life history and genetic differences. Since these now exist for the Cherry Point herring stock, the Stout et al. (2001) primary basis for a broad DPS evaporates. Hutchings (2001:118) reached the following conclusion on this subject:

"The logical fallacy of this argument lies, of course, in the premise that species, in general, are adapted to colonise new areas. Rather, natural selection tends to select against genotypes that abandon the environments and habitats in which they evolved and to which they have adapted their life histories, spawning times, and migratory behaviour, particularly in the absence of any density-dependent pressure to do so."

For situations such as Cherry Point herring, the prevailing geographic mind-set for DPS definition needs to be broadened. In this particular case, the proper DPS should be defined by significant life history differences (mainly spawn timing and spawn locations) plus detectable genetic differences within a geographic area shared with another herring DPS. Stout et al. (2001) used anecdotal evidence of a previous herring population decline and subsequent recovery as part of their rationale for the metapopulation hypothesis. However, in the absence of any quantitative data, it is impossible to determine roles of fishing mortality in the decline or environmental change in the recovery.

It might be argued that the Cherry Point herring stock should be evaluated under a completely different category such as "Specialized Habitat Requirements" (Musick 1999:12) but proponents for additional industrial development have argued that there are no significant habitat problems and Stout et al. (2001) did not even consider this alternative. It has always been very difficult to establish unambiguous quantitative relationships between fish habitats and fish populations. A herring stock in nearby Discovery Bay has declined sharply but habitat is relatively pristine and other herring stocks are subjected to similar levels of chemical contaminants but have not declined. Existing AFS criteria cannot provide needed protection if a significant quantitative correlation to fish habitat parameters is required.

The obvious solution for this and other fish populations subjected to depensation is that AFS criteria need to be modifed. A new category must be added to classify any population with a quantitative expression of depensation as Threatened. The specific burden of proof needs to be an expression of depensation itself, not conclusive proof of definite causes. Immediate, active ecosystem management intervention is needed anytime a fish population enters a range of abundance where it becomes unable to replace itself on a sustainable basis.

The existing AFS criteria also reach an illogical end-point at the Vulnerable level. An objective, quantitative approach suddenly becomes subjective. Table 4 in Musick (1999:12) gives "Decline thresholds for four categories of DPSs based on population resilience." but proceeds to state that "If a decline reaches a threshold, the DPS would be listed as *vulnerable* and subjected to close scrutiny for further listing." However, there are no specific criteria or quantitative measures to define how this might be done. In practice, some populations will reach the Vulnerable level but will advance no further in the face of inevitable arguments over meaning of some very vague guidance. The addition of a new category for populations subject to depensation would at least solve the problem for high risk stocks. Populations which benefit from compensation at low abundance levels will probably survive in spite of us.

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